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DEPARTMENT OF BUILDING TECHNOLOGY

"USE OF FUSED LATERITE POWDER AS A PARTIALLY REPLACEMENT FOR CEMENT IN CONCRETE"

By

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A dissertation submitted to the Department of Building Technology in Partial Fulfillment of the requirement for the award of Master of Science in Construction Management

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DECLARATION

I hereby declare that this submission is my own original research to the degree of MSc in Construction Management and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of this University or any other institution except where duly references have been acknowledged.

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DEDICATION

I dedicate this work to God Almighty for his love and protection. It also goes to my beautiful wife, Twenewaa Beatrice and my children Obour Victor Gyau, Obour Kyere Gyau, Obour Kwadwo Kyere and Obour Nhyira Korang.

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ABSTRACT

The high cost of Portland cement (which is produced from imported raw material) in Ghana makes building construction very expensive thereby making many people unable to afford. Consequently, there is a quest to find a substitute for cement. Fused laterite (Laterite rock) is a material abundant in Ghana which naturally portrays the properties of a cementitious material. However, knowledge on this local material is limited. Thus the current study aimed at exploring the properties of this material and its effects on the strength of concrete when used as partial replacement of cement in concrete production. To achieve this 150mm concrete cubes and 150mm x 300mm concrete cylindrical specimen were cast and tested for their compressive and split tensile strengths respectively. Chemical analysis of the material was also carried out to find out the compounds/oxides present in the fused laterite. The results revealed that the most dominant chemical in fused laterite is Calcium Oxide (CaO) which represents 19.2% followed by Silica oxide (2.8%), Sulphur oxide (2.5%), Magnesium oxide (1.94%), Sodium oxide (0.06%) and Potassium oxide (0.04%). Thus fused laterite contains a majority of the oxides (chemicals) present in Ordinary Portland cement. However, the quantities of the chemicals are small compared with that in Portland cement thereby making it difficult to be used solely as the binding agent in concrete production. Moreover, fused laterite reduces the compressive and split tensile strengths of concrete as its content in the mix increases. The above effect was attributed to the fact that fused laterite contains little amount of silicate (the primary chemical responsible for strength development). Thus, as more of the fused laterite is used, the content of silicate in the mix is reduced hence a weak concrete is produced. Based on the findings, recommendation was made for further studies to find an effective way of using fused laterite for the production of cement.

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CHAPTER ONE

GENERAL INTRODUCTION

1.1 BACKGROUND OF THE STUDY

High cost of building materials has become a problem for the construction industry in developing countries such as Ghana where clinker for the production of Ordinary Portland Cement is imported. This has led to the high cost of cement price since most of the construction works are made by Ordinary Portland Cement (Lamudi, 2015). Most of the researchers in construction industry are doing their best to minimize cost of construction materials by the use of available local materials in the area (Joshua et al, 2014).

Fused Laterite (Laterite Rock) is a type of soil formed by strong, prolonged weathering and becomes a rock (World of Earth Science, 2003). Fused Laterite is also described as a reddish ferruginous soil formed from weathered rocks (Hudson, 2004). According to Walker and Pavia (2010), Pozzolana are materials formed from the reaction of calcium hydroxide usual when moisture or water is present. The product of the hydration includes calcium aluminate hydrates and calcium silicate hydrate. Zakari and Akani (2013), explained that Ghana is full of natural resources and fused laterite is one of the resources that can be found in many communities in the country. It is a hard rock and contains high silica content which is known to prolong the setting time of concrete and hence produces high strength of concrete. Though it is used as a building material it is not used as Pozzolana for concrete production. According to Ghassan et al (2013), researchers have shown that replacement of fly ash, rice husk, blast furnace slag, egg shell etc. in concrete can improve concrete workability and durability. They can also provide resistance to all sulfate attack and alkali silica reaction.

1.2 PROBLEM STATEMENT

Most concrete structures are constructed using Ordinary Portland Cement as the main type of cement. The high cost of cement has made building construction very expensive such that many people cannot afford due to the importation of the raw materials for cement production. Fused laterite (Laterite Rock) which is a cementitious material is in abundance in Ghana and can be used as partially replacement of cement in concrete production to reduce the high cost of cement.

1.3 AIM AND OBJECTIVES

1.3.1 Aim

The aim of the study was to find out how the partial replacement of cement with fused laterite affects the strength properties of concrete.

1.3.2 Objectives

The objectives of the study were

(i) To find the chemical properties of fused laterite powder;

(ii) To find how the partial replacement of cement with fused laterite affects the Compressive strength of concrete; and

(iii) To find how the partial replacement of cement with fused laterite affects the Split tensile strength of concrete.

1.4 SCOPE

The current study sought to investigate into the possibility of using locally available fused laterite powder as partial replacement of cement in concrete production. The study focused on the chemical properties of the material and the influence of the chemicals on the tensile and compressive strengths of concrete.

1.5 METHODOLOGY

Research methodology deals with methods and techniques used in undertaking a study. The research process commenced with an extensive review of existing literature on the composition of cement and the effect of its constituent materials on its strength properties.

Experiments carried out in the laboratory were used to collect data. Standard 150mm concrete cubes were used for the compressive strength tests whilst tests for the tensile strength of concrete were carried out on standard 150mm x 300mm concrete cylinders. The tests were carried out using a 2000KN capacity hydraulic test machine. The data collected were analyzed using Microsoft excel. Based on the findings of the study, recommendations were made.

1.6 SIGNIFICANCE OF THE STUDY

The cost of cement and cement is likely to reduce if fused laterite which is abundant in Ghana can be used as a binding material to replace cement in concrete production.

1.7 ORGANIZATION OF DISSERTATION

The dissertation was organized into five interrelated but distinct chapters. The first chapter is the introduction to the whole work. It covers the background and the research problem, the aim and objectives of the study, research scope, methodology and justification for undertaking the study. Chapter two reviews existing literature on the topic. The review was purely based on grounded theory that looks at literature with close relationship with the subject area. The methodology used for undertaking the study is encapsulated in chapter three. Here the research design, research strategies and the data collection and analysis tools used for the study are spelt out. This chapter is followed by the chapter four that contains the analysis and discussion of the results. The results of the tests were then compared to findings established from the literature. The study rounded up in the fifth chapter with the conclusions, summary of the findings and consequently practical implications for further studies were highlighted.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

Concrete is a mixture of fine aggregate (sand), coarse aggregate and cement with water added to aid the hydration process. Previously cement was used as the main binding agent in concrete production however, these days concrete mixes contain additional cementitious material as one of the components of the mix. The additional cementitious materials are usually from the products of other processes or materials. Examples include pozzolans. Even though not all of these materials have cementitious properties, when they mix with the ordinary cement they react to form binding agent. Concrete mixes with high Portland cement contents are venerable to cracking and increase heat generation, but these effects can be controlled to a certain degree by using supplementary cementitious materials (National Ready Mixed Concrete Association, 2000).

According to Rajendra et al (2013), cement producers generate a lot of carbon dioxide (CO_2) to pollute the environment, meanwhile studies have clearly indicate that there is a strong need to explore the possibilities of using material that can reduce the carbon dioxide (CO_2).This can be achieved by the use of processed additional cementitious material.

2.2 CATEGORIZATION OF CEMENTS

As indicated by Neville (1996) and the Portland Cement Association (2015) various types of cements exist globally for different purposes. They include White Cement, Rapid Hardening Cement, High Alumina Cement, Quick setting cement, Sulphates resisting cement, Low Heat Cement Blast Furnace Slag Cement, Coloured cement, Air Entraining Cement Pozzolanic Cement, and Hydrographic cement. The composition and uses of each type is presented on Table 2.1.

Survey conducted by Portland Cement Association in 2013 revealed that World cement consumption in 2010 was 3,313 million metric tons. Out of this developed countries consumed 9.4% whereas China and India consumed 57.7% and 7% respectively. The remaining 25.9% were consumed by emerging countries. The report further suggested that the annual consumption is expected to increase by about 4.0% in 2016.

Table 2.1: Common Types of cement used (Portland Cement Association, 2015)

Types	Composition	Use
Rapid Hardening Cement	High Lime content	Commonly used for structures where high strength is required at the early stages
Quick setting cement	Small content of aluminum sulphate as a catalyst to speed up the rate of setting	Used for works concrete works in water such as dams, bridges

Low Heat Cement	Small content of tri-calcium aluminate	Used for concrete projects such as gravity dams
Sulphates resisting Cement	Containslow tricalcium aluminate (usually below 6%)	Concrete structures exposed to sulphate attacks such as canals.
Slag Cement	Produced from clinkers with about 60% slag	Suitable for works which cost considerations is prime.
High Alumina Cement	Produced from bauxite, lime and clinker.	Concrete structures exposed frost attack, high temperatures, acid, etc.
White Cement	It is prepared from raw materials free from Iron oxide.	It is used for artistic purposes such as facing panels, terrazzo surface etc.
Coloured cement	Produced from a mixture of pigments and ordinary cement.	Commonly used for decorative works
Pozzolanic Cement	Pozzolana is mixed with portland cement	Suitable for marine structures
Air Entraining Cement	Air entraining agents such as glue, resins, glues etc. are added to clinkers during the production process.	It is used purposely to improve workability of concrete and enhance the ability of the concrete to resist frost attacks.
Hydrographic cement	Produced from repelling chemicals	The cement improves workability and strength

2.3 PORTLAND CEMENT

Portland cement is currently the most commonly used cement globally. ASTM 150M groups Portland cement into five types. The main difference in the cements is the content of tricalcium Aluminate (C_3A) in each of them. Moreover their fineness, rate of hydration and their resistance to sulfate attack also varies. Table 2.2 describes each of the cement types. Tables 2.3 and 2.4 show the oxide and mineral composition of each of the cements. Despite the differences, each of the cement contains about 75% by weight of calcium silicate minerals. The cements are often referred to as Ordinary Portland cement (OPC). Two of them (i.e. Types II and V) have the ability to resist sulfate attack thus making them the preferred choice when it comes to concrete structures subjected to severe attack by sulphate. Type II and Type V cement has low content of C_3A. Type I and Type II cements on the other handed virtually have no significant difference hence it is common to find cements with the designation “Type I/II”.

Type III cements are known to develop early strength more quickly. This makes them useful for concrete structures where early strength development is important. In cold climates, Type III cements help to considerably reduce the rate of hydration and strength gain. The disadvanges in the used of rapid-reacting cements are greater heat of hydration, shorter period of workability, and a slightly lower ultimate strength (ASTM 150M-2015, Neville 1996, Portland Cement Association 2015)

Type III concrete are used in structures exposed to excessive temperature. Type IV cements on the other hand release heat and gain strength more slowly than Type I cements.

White cement is made from materials containing low iron and magnesium. These elements give the cement its colour architectural purposes (Neville 1996, Portland Cement Association 2015)

Table 2.2: Classification of Portland cement per ASTM 150M (2015)

Type	*Classification*	*Composition*	*Applications*
Type I	General purpose	Moderately high C_3S content. Good for early strength development	General construction
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration	Low content of C_3S (<50%) and C_3A	Massive structures such as dams.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Concrete works exposed to sulfate attack

White	White color	No C_4AF, low MgO	Decorative

2.3.1 Chemical composition of Portland cement

The primary constituents of Portland cement are iron, silica, lime, alumina oxides. The interaction of these oxides results in the formation of four compounds as shown on Table 2.3 (Neville, 1996). The silicates in cement are not pure compounds, but contain minor oxides in solid solution. The different types of cement we have nowadays are produced by varying the proportions of the various compounds. Table 2.4 gives the oxide composition limits of Portland cement.

Table 2.3: Composition of Portland cement (Neville, 1996)

Name of compound	Oxide composition	Abbreviation
Tricalcium silicate	$3CaO.SiO_2$	C_3S
Dicalcium silicate	$2CaO.SiO_2$	C_2S
Tricalcium aluminate	$3CaO.Al_2O_3$	C_3A
Tetracalcium aluminoferrite	$4CaO.Al_2O_3.Fe_2O_3$	C_4AF

Table 2.4 limits on the composition of Portland cement (Neville, 1996)

OXIDE CONTENTS	Content (%)
CaO	60-67
SiO_2	17-25
$A1_2O_3$	3-8
Fe_2O_3	0.5- 0.6
MgO	0.4- 4.0
Alkalis (as Na_2O)	0.3-1.2
SO_3	2-3.5

Table 2.5 Oxide and compound composition of a typical Portland cement of the 1960s (Czernin 1962 cited in Neville, 1996)

Typical oxide composition	(%)
CaO	63
SiO_2	20
$A1_2O_3$	6
Fe_2O_3	3
MgO	1.5
SO_3	2
Alkalis	1
Loss of ignition	2
C_2A	10.8
C_3S	54.1
C_2S	16.6
C_4AF	9.1

The various compounds affect the strength of cement in different ways. The two silicates (C_2S and C_3S) are responsible for the strength gain of hydrated cement paste. While C_3S influences strength development during the early days (usually the first 4 weeks), C_2S contribute to strength gain afterwards (Woods et al, 1932 cited in Neville, 1996). According to Neville (1996) pure C S and C S have strength of about 70N/mm² at the age of 18 months. However, at the age of 7 days, C S have no strength while C S have strength of 40 N/mm².

The other compounds also play key role in strength development. C A contributes to strength development from 1 - 3 days and even longer. It must be noted however that at longer days, C Ahas retrogressive effect on strength especially for cements with high$C$ A or (C A + C AF) content. (Bogue and Lerch, 1934 cited in Neville 1996).

2.4 POZZOLANA CEMENT

Canadian Standard Association (2000), defines Pozzolan as a material which in itself possesses little or no cementing property, but in the presence of moisture reacts with calcium hydroxide to form compounds which has binding characteristics. According to (National Ready Mixed Concrete Association, 2000). Pozzolana main function in concrete is to enhance the workability, durability and strength. These purposes allow the concrete manufacturer to design the best concrete mixture to suit preferred mixture. Pozzolanas and supplementary cementitious materials either natural or artificial are often used as cement replacement or as an improvement in concrete. Physical or chemical properties of the material determine their pozzolanic or cementitious properties

2.4.1 Classification of Pozzolana

American Concrete Institute (2000), classified Pozzolans into two categories, either natural or artificial, depending on their source. Natural pozzolans are either raw or calcined natural material-such as ash, opalinechert, tuff, some shale, or some diatomaceous earth that have pozzolanic properties. Artificial pozzolans are mostly from by-product materials. For instance silica fume obtained from the production of ferrosilicon alloys and silicon metal.

2.4.2 Pozzolana Materials

According to Canadian Standard Association (2000), Pozzolanic materials in themselves possess little or no cementitious value, but when in powder form and in the presence of water reacts with calcium hydroxide to form compounds which has binding features. Moreover, they contain silicon and aluminum. Generally, pozzolans can be grouped into natural and artificial Pozzolana as shown in Table 2.6.

Table 2.6: Types of Pozzolana

Type	Materials
	Clay and Shale

Natural Pozzolana	Optline chert
	Diatomaceous earth
	Volcanic tuffs and Pumicities
Artificial Pozzolana	Fly ash
	Blast furnace
	Silica fume
	Rice husk
	Metakaoline
	Surki

Source :(American Concrete Institute, 2000)

Generally most Pozzolana materials in concrete are fly ash and blast furnace slag.

2.4.2.1 Fly Ash

Dabhade et al (2013), also explained that, Fly ash as a product from the burning of coal. It is conveyed and collected by flue gases and electronic precipitator respectively. It is the most commonly used Pozzolana material globally. It is widely used producing high strength and high performance concretes. Table 2.6 shows the constituents of fly ash compared with ordinary cement.

Table 2.6: Composition of Fly Ash and Cement (Dabhade *et al*, 2013)

Chemical Composition	Cement %	Fly ash %
SiO_2	20	66.82
Fe_2O_3	3	6.33
$A1_2O_3$	6	20.97
CaO	64	2.43
MgO	3.5	0.80
SO_3	2	2.51
Alkalies	0.6	0.34

2.4.2.2 Rice Husk

According to Shah et al (2013), Rice husks are procedure from paddy rice. Typically, 40kg of ash can be obtained from 1000 kg of paddy rice. Due to its nutritional value, rice husk is also use as animal feed. The used of rice husk in the production of Pozzolana cement helps to effectively disposed the waste. Moreover it is also use to generate electricity. Table 2.7 shows the chemical composition of a typical rice husk.

Table 2.7 Chemical Properties of Rice Husk Ash (RHA) (Shah *et al*, 2013)

Composition	**Weight % RHA**
Silicon dioxide, SiO_2	87.2
Aluminum oxide, $A1_2O_3$	0.15
Ferric oxide, Fe_2O_3	0.16
Calcium OXIDE, CaO	0.55
Magnesium oxide, MgO	0.35
Sodium oxide, Na_2O	1.12
Potassium oxide, K_2O	3.68
Phosphorous oxide, P_2O_5	0.50
Titanium oxide, TiO	0.01
Sulphur, SO_3	0.24
Carbon, C	5.91
Loss on Ignition	8.55

2.4.2.3 Egg Shell

From the study of Shah et al (2013), it was found that calcium carbonate is the main chemical in eggshells. This chemical is estimated to be 95%. Other chemicals such as Phosphorous, Magnesium, Aluminum, Ironic acid, Sodium, Copper Potassium, Zinc, Iron, and Silica make up 5%. Moreover; eggshell is reported to contain amino acids, a good bio-sorbent. Table 2.8 shows the constituents of eggshell as reported by Praveen et al (2015).

Table 2.8 Chemical Properties of Egg shell (Kumar *et al,* 2015)

OXIDE CONTENTS	PERCENTAGE (%)
CaO	60-67
SiO_2	17-25
$A1_2O_3$	3-8
Fe_2O_3	0.5-6.0
MgO	0.1- 4.0
K_2O, Na_2O	0.4-1.3

SO_3	1.3-3.0

2.4.3 Benefits of Pozzolana

American Concrete Institute (2000), research shows that Pozzolans are not only strengthens the concrete, but they have the following benefits as well:

(i) **Economical**: For all other things being equal, concrete produced from pozzolans less costly than ordinary Portland cement.

(ii) Concrete produced from pozzolans continues to gain increasing strength with time (iii)**Low Permeability**: Pozzolana decreases the permeability of concrete.

(iv) Pozzolana concrete has the ability to resist the attack by aggressive compounds and hence increases concrete durability.

(v) Besides the above, pozolana has other benefits such as reduction in shrinkage, low heat production, improve workability etc.

2.5 FUSED LATERITE (LATERITE ROCK)

Laterite is described by Rahardjo et al (2004) as a product of in situ weathering of igneous, sedimentary, and metamorphic rocks commonly found under unsaturated conditions. Thus laterites are residual of weathering and decomposition. The formation process involves the leaching silica, bases and accumulation of oxides of iron, aluminum or both in process known as laterization. Laterites are rich in iron and aluminum oxides, silicates and sometimes kaolinite. The colour of lateritic soils is red (Abebaw, 2005).

2.4.4 Uses of Laterite

Lateritic soils are widely used as a construction material in Ghana and other developing countries of the world. In addition to mud walls, brick masonry (dried or burnt type) are made from lateritic soils in rural areas of the country. Research has shown that laterite can

be used to replace sand component of concrete either wholly or partially and is becoming widespread among the low income earners for building construction. The utilization of laterites enables the provision of low-cost houses and other rural infrastructures. That notwithstanding, their extent of utilization is very low. This is probably due to lack of adequate data needed in the design of structures using this material. Lateritic soil has been one of the major building materials (Osadebe and
Nwakonobi, 2007).

2.5 COMPRESSIVE AND SPIT TENSILE STRENGTHS OF CONCRETE

2.5.1 Compressive strength

The strength and quality of concrete is measured terms of its compressive strength. In the United Kingdom, this parameter is determined based on the 28 day-cube strength of concrete specimen; that is the crushing strength of 150mm cubes at an age of 28 days after mixing. In some cases, 100mm cubes are used. In the USA, 150mm x 300mm nominal cylinder specimens are tested to determine the cylinder strength. The cylinder strength is usually taken as about 70 -80% of the cube strength (Kong and Evans 1994).

Several factors affect the strength of concrete and they include the following: aggregate, water/cement ratio, cement type, additives, curing conditions, rate of loading, and age at testing (Neville, 1996; Kong and Evans, 1994). Few of the factors are discussed below:

(i) **Water/cement ratio**: Strength of concrete is primary dependent on the water/cement ratio (w/c). All other things being equal, the higher, the w/c ratio the lower the strength of concrete.

(ii) **Characteristics of the aggregates**: Properties such as size, shape, surface texture and grading affects the strength of concrete principally by affecting the w/c ratio required for workable concrete.

(iii)Curing: The strength of concrete improves with proper curing. Curing is the provision of moisture and favorable temperature for cement to hydrate, thereby increasing the strength of the concrete (Entroy 1960 cited in Kong and Evans 1960)

2.5.2 Split Tensile Strength

The tensile strength of concrete is important in resisting cracking from shrinkage and temperature changes. Nowadays, tests are rarely carried out to measure directly the tensile strength of concrete (referred to as direct tensile strength) mainly due to the difficulty of applying a truly concentric tensile load to the specimen. Hence another method is applied to measure the indirect tensile strength sometimes referred to as the split tensile strength (Kong and Evans, 1994). The test which was developed independently in Brazil and Japan consists essentially in loading a standard cylinder (150mm x 300mm diameter) across a diameter until failure. This usually involves

splitting of the concrete.

ASTM C496 calculates the splitting tensile strength f_t using the formula

$f_t = \frac{2P}{\pi LD}$(N/mm²) ……………………………………………………… (2.1)

Where P = Maximum force applied to the specimen (N)

d= the diameter of the cylindrical specimen (mm) *l* =

length of the cylinder (mm)

Ideally, the splitting tensile strength is calculated directly on concrete samples under uniform stresses. However, this is difficult to achieve in an experimental set up. To avoid the demanding and time-consuming direct measurements of the splitting tensile strength, engineers and researchers have tried to estimate the splitting tensile using the compressive strength. Generally, the tensile strength of concrete is estimated as being proportional to the square root of the compressive strength (Choi and Yuan, 2005). Moreover splitting tensile strength increases with an increase in the compression strength. Below are some formulas proposed by various codes and scholars as guide in predicting the cylinder strength of concrete in terms of the compressive strength.

$f_{spt} = 0.3\,(f_c)^{2/3}$ ……………………………..… CEB-FIB (1991)

$f_{spt} = 0.59\,(f_c)^{1/2}$ ………………………..……ACI 363 R-92 (1992)

$f_{spt} = 0.56\,(f_c)^{1/2}$ ……………………………. ACI 318-99 (1999)

Where f_{spt} and f_c are expressed in MPa.

2.6 SUMMARY

In this chapter, the types of cement used for concrete production have been discussed. The chemical compositions of Portland cement and Pozzolana cement have also been presented together with the role of each of the compounds of cement properties. Literature was also reviewed on fused laterite which is central to the current study. From the review it was found that no data exists on the chemical composition of the fused laterite. Moreover, no literature exists to explain the effect of fused laterite on the strength properties of concrete. Based on these gaps, the current study is designed to find the chemical composition of fused laterite and its effect on the concrete strength.

CHAPTER THREE

MATERIALS AND METHODS

3.1 INTRODUCTION

This chapter deals with methods and techniques used in the collection of data as a justification for the suitable approach to the study. Several methods were considered, taken into account the aims and objectives of the research.

3.2 RESEARCH DESIGN

The current study is a descriptive research which employs a quantitative research approach. For such cause and effect investigations, Fellow and Liu (2008) recommend the use of experiment. Thus the current research involved series of laboratory works to measure the strength of concrete produced with fused laterite as a partial replacement of cement.

3.3 PREPARATION OF SPECIMEN

3.3.1 Materials

The materials used for this research include: Ordinary Portland Cement (OPC), fused laterite Pozzolana, quarry chippings, pit sand and water which were all obtained from various places in the Brong Ahafo Region.

(i) Ordinary Portland cement (OPC)

Ordinary Portland cement of grade 42.5R manufactured by Dangote, a local cement manufacturers in Ghana was used for the preparation of the cube and cylinder concrete specimens.

(ii) Fused laterite Pozzolana

The fused laterite Pozzolana used in this research was natural raw material obtained from Fiapre near Sunyani. The laterite was in the form of rock bolder which were broken into smaller sizes and subsequently milled into powder form. The powder was sieved through BS Standard sieve 75micron to have a fined powder for the research.

(iii) Fine aggregate (Pit sand)

Ordinary pit sand obtained from Wenchi, was used for the concrete mixes. The sand was put into oven of temperature of 120^{o}C for 24 hours to remove any moisture from it.

(iv) Coarse aggregate

The Coarse aggregate used for this research was graded crushed granite stone obtained from Vision quarry factory in Wenchi District. The coarse aggregate was sieved to determine the particle sizes distribution of the coarse aggregate.

(v) Water

The water used for the concrete mixes was drinkable water. The water-cement ratio used for the mixes was 0.5

3.3.2 Casting of cubes

The concrete mix proportion of 1:2:4 was used throughout for the mixes. The materials were measured by weight using electronic weighing machine. The percentage of fused laterite in the mixes was varied from 0%, 10%, 20%, 30% and 40%. The samples produced were six every mix which made a total of 30 for cubes and 30 for cylinders including control mixture. The concrete cubes produced were of size 150mmx150mmx150mm and 150mmx300mm for concrete cylinders. The percentage replacement of fused laterite used is shown in the Table 3.1. From the concrete mix design, a cement content of 7.43kg was required to produce concrete with compressive strength of 30N/mm^2. Based on this value, the content of fused laterite for the other specimen were calculated accordingly.

Table 3.1: Percentage replacement of fused laterite

% Replacement of fused laterite	Fused Laterite (FL) kg	Ordinary Portland Cement (OPC) kg
0 %	0.00	7.43
10 %	0.743	6.687
20 %	1.486	5.944
30 %	2.229	5.201
40 %	2.972	4.458

3.3.3 Curing of specimen

The specimens were removed from the moulds a day after casting and cured in water for 7 and 28 days prior to the testing.

Fig 3.1: Boulders of fused literate used.

Fig 3.2 Sieving of fused laterite powder

Fig 3.3: Curing of specimen

3.4 TEST PROCEDURE

3.4.1 Compressive Strength

The 150mm concrete cube specimen that were cast were used to determine the compressive strength for each of the mixes with 0%, 10%, 20%, 30%, and 40% replacement of fused laterite. After curing, the specimens were tested by hydraulic compressive strength testing machine which has a capacity 2000KN as shown in Fig 3.4.

The test was carried out per the procedures specified in BS EN 12390-3 (2002).

Fig 3.4: Compressive Strength Test

3.4.2 Split Tensile strength Test

Standard 150mm x 300mm concrete cylinders were used to determine the split tensile strength for each of the mixes with 0%, 10%, 20%, 30%, and 40% replacement of fused laterite in the concrete. After curing, the specimens were tested by hydraulic compressive strength testing machine which has a capacity 2000kN. The test was carried per the procedures specified in BS EN 12390-6 (2000)

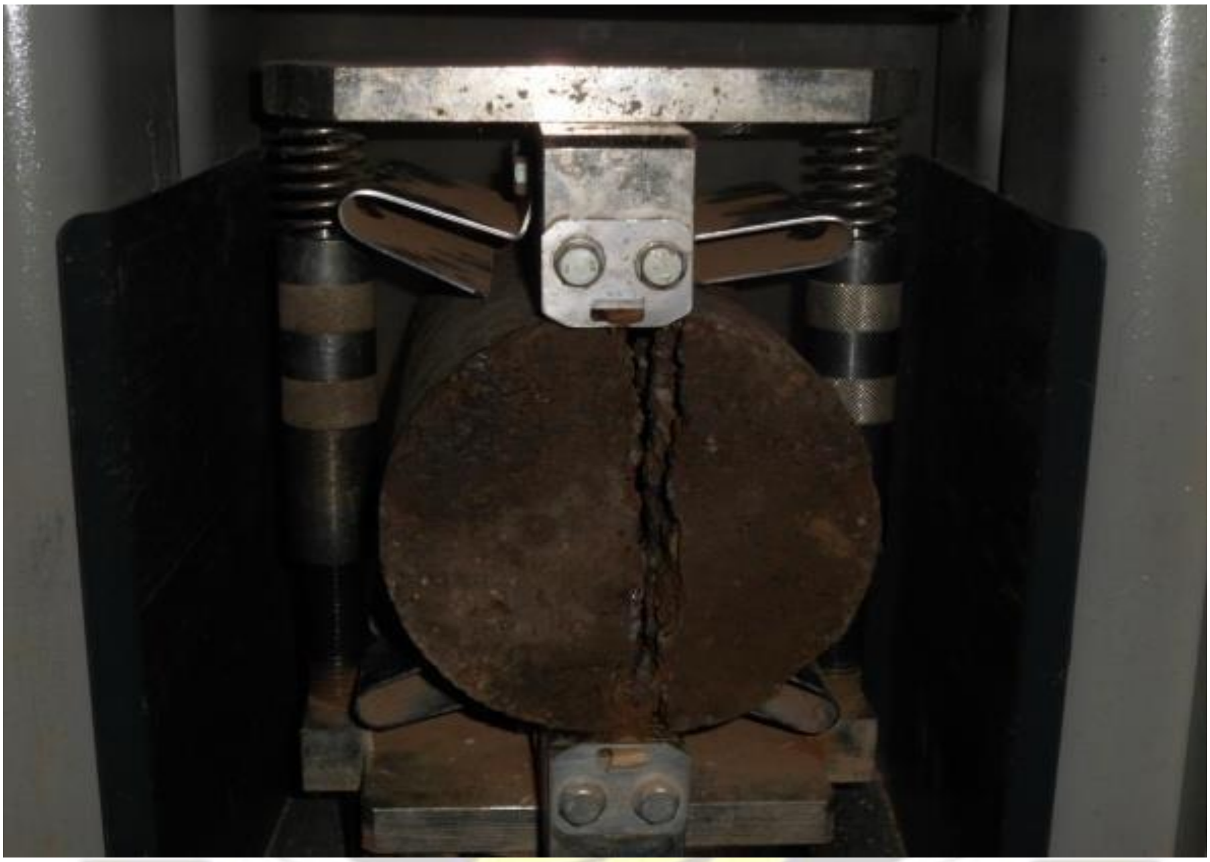

Fig 3.5: Split Tensile Test

3.4.3 Procedure for Chemical analysis of Fused Laterite

100g of sample was dissolved in 1000ml (1lit) of distilled water and the various chemical analyzed as follows:

(i) Magnesium Oxide

- Method: titration
- Measured 100ml of sample
- Determining of total hardness and calcium hardness by using 0.02m EDTA, 10% ammonium buffer solution and 5% eriochromeblackit and murexid indicator 0.5ml
- The results was calculated as follows:

Total hardness – calcium hardness = magnesium hardness

:. Magnesium hardness x 0.243 (factor) = magnesium oxide

Ethylene DTA mine tetra acetic acid Dt sodium salt (EDTA)

(ii) Aluminum Oxide

 Instrument: DR 2000

(1) Enter the stored program number for aluminum. Press 10 read/enter rotate the wavelength dial to 522 num.

(2) A 50ml graduated cylinder was filled with the sample.

(3) Add the contents of one ascorbic acid powder pillow.

(4) Add the contents of one aluver 3 aluminum reagnant powder pillow.

(5) Add contents of one bleaching 3 reagent powder pillow to the 25ml of the mixing graduated cylinder (A red-orange colour develops TP aluminum oxide)

(6) Press shift timer – A15 – minute reaction period will begin. After some time, the result will display in mg/L

(iii) Calcium Oxide

- Method – direct measurement ISE method
- Instrument: HACH PHISE meter
- Instrument was calibrated with standard solution
  - ✓ The electrodes were removed and rinse with deionized water. 25ml of sample was measured calcium ISA powder pillow was added. A magnetic stir bar was added and the beaker was place on and electromagnetic stir and begins stirring out a moderate rate.
  - ✓ The electrodes are place in the sample and press the electrolyte dispenser button. The result is displace mg/L.

(iv) Ferric Oxide

- Method – phenithriline
- Enter the stored program number 255. Rotate the wavelength to 510mm. fill on sample cell with 25ml sample. Add ferric reagent powder pillow to the sample. Press shift time, a three minute reaction period with begin. Fill a second sample cell (the blank) with 25ml. press zero and place the prepared sample into the cell holder, close the light shield. Press read/enter then result will be displacing in mg/L.

(v) Sodium Oxide

- Direct measurement ISE Method Instrument- Hach PH/ISE meter calibration of instrument with standard solution. Rinse the electrodes with deionized water and blor dry, pour the 25ml sample into a beaker. Add the contents of one sodium and potassium ISA powder pillow. Stir the magnesic bar. Place the electro bar in the sample and press the electrolyte dispenser's button. The result will displace in mg/L

(vi) Sulphur Oxide

- Measured 100ml of sample, do not agitate add the contents of dissolved oxygen 3 reagent powder pillow. Stir gently to mix. Add one diopperful of starch indicator solution. Stir gently to mix fill on 10ml burer to the zero mark with 0.0125m potassium iodide – iodide standard solution. Titrate the prepared sample while gently swirling the stark, until a permanent blue colour appear.
- Calculate: resultSulphur mg/L = Titrant use X 10 (factor) (ml)

The rest of the chemicals were analyzed following similar procedure.

3.5 DATA ANALYSIS

The data obtained from the laboratory results was analysed using Microsoft excel version 13. The relationship between the compressive strength and the percentage replacement of fused laterite in a given mix was established. Similar analysis was done for the split tensile strength.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter presents the results of the laboratory experiments carried out. The results are analyzed and compared with literature to find out the relationships that exist between the two. The chapter has been organized into different sections in accordance with the objectives of the study.

4.2 CHEMICAL COMPOSITION OF FUSED LATERITE

The study, as one of its main objectives, sought to find out the chemical composition of fused laterite. The results are shown in Table 4.1. Comparison in made between fused laterite and Ordinary Portland Cement used for the study. The results revealed that the most dominant chemicals in fused literate are Calcium Oxide (CaO) which represents 19.2% followed by Silica oxide (2.8%), Sulphur oxide (2.5%), and Magnesium oxide (1.94%) respectively as shown in Table 4.1. Taking a critical look at the results, one would observe that fuse literate contains a majority of the oxides (chemicals) present in Ordinary Portland cement. It is therefore not surprising that fuse literate exhibits the properties of cement. Notwithstanding the above, the quantity of the chemicals in fuse literate are small compared with that in Portland cement thereby making it difficult to be used as a binding agent in concrete production. See the limit of oxide composition for Portland cement in Table 2. 4.

An effort was also made to compare the results with the chemicals in other materials such as fly ash and ash from rice husk. Silica oxide dominates the chemicals in Fly ash and RHA than the other chemicals. Their quantity meets the requirement for cement production. From literature (Woods et al 1932 cited in Neville, 1996) it was found that the two silicates (C_2S and C_3S) in Portland cement are responsible for strength development of hydrated cement paste.C_3S influences strength development during the early days (usually the first 4 weeks), while C_2S contributes to strength from 4 weeks onwards. On this note, it can be concluded that concrete produced using fly ash or RHA will develop more strength than one produced from fused laterite to the high silicate content. Comparing the three, fly ash will perform better than RHA or fuse laterite concrete.

The study done by Shah *et al* (2013) also revealed that egg shell is about 95% $CaCO_3$. With the remaining 5% being Magnesium, Aluminum, Phosphorous, Sodium, Potassium Zinc, Iron, Copper, Ironic acid and Silica acid. The above results also suggests egg shell also has some properties similar to fused laterite.

Table 4.1: Chemical Composition of the Fused Laterite compared to other cementitious materials

Oxide	Fused laterite$^{\alpha}$ %	OP Cement$^{\alpha}$ %	Fly ash* %	Rice Husk^{+} Ash %
Silica oxide (S_1O_2)	2.8	21.7	66.82	87.2
Aluminum oxide ($A1_2O_3$	0.64	6.6	20.97	0.15
Ferric oxide (Fe_2O_3)	0.4	4.0	6.33	0.16
Calcium oxide (CaO)	19.2	60.0	2.43	0.55
Magnesium oxide (MgO)	1.94	20.5	0.80	0.35
Sodium oxide (Na_2O)	0.06	0.4	-	1.12
Potassium oxide (K_2O)	0.04	0.39	0.34	3.68
Sulphur oxide (SO_3)	2.5	2.2	2.51	0.24

Source: + = Shah*et al* (2013), * = Dabhade*et al* (2013); α = Field Data (2015)

4.3 STRENGTH PROPERTIES OF CONCRETE WITH FUSED LATERITE

4.3.1 The Compressive Strength

The study also sought to find out the influence of fuse laterite on the compressive strength of concrete. The results for the specimen at the ages of 7 and 28 days are shown in Figs 4.1 and 4.2. The results revealed at irrespective of the age of the concrete, fuse laterite reduces the compressive strength of concrete as it's (i.e. the fuse laterite) percentage in the mix increases. The curve slopes downs from the left to the right. At the age of 28 days, the following relationship is proposed the compressive strength of concrete in terms of the percentage of fuse laterite used in a given mix.

$f_{cu} = -0.4834x + 41.27$

Where x = the percentage of fuse laterite used in a given mix. The relationship above shows at the presence of fuse laterite has retrogressive effect on concrete strength. The above effect can be attributed to the fact that fused laterite contains little amount of silicate (the primary chemical responsible for strength development). Thus, as more of the fused laterite is used, the content of silicate in the mix is reduced hence a weak concrete is produced. The above results confirm the study by Woods et al (1932) cited in

Neville (1996).

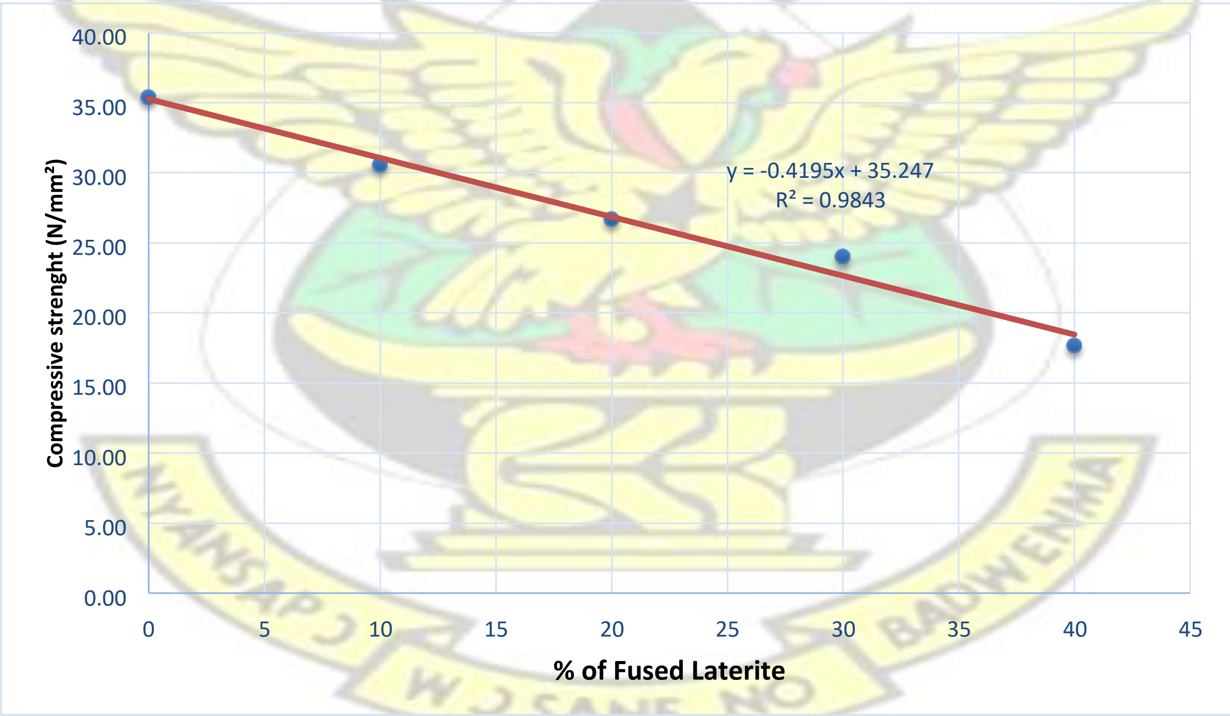

Fig 4.1: Compressive strength at 7 days

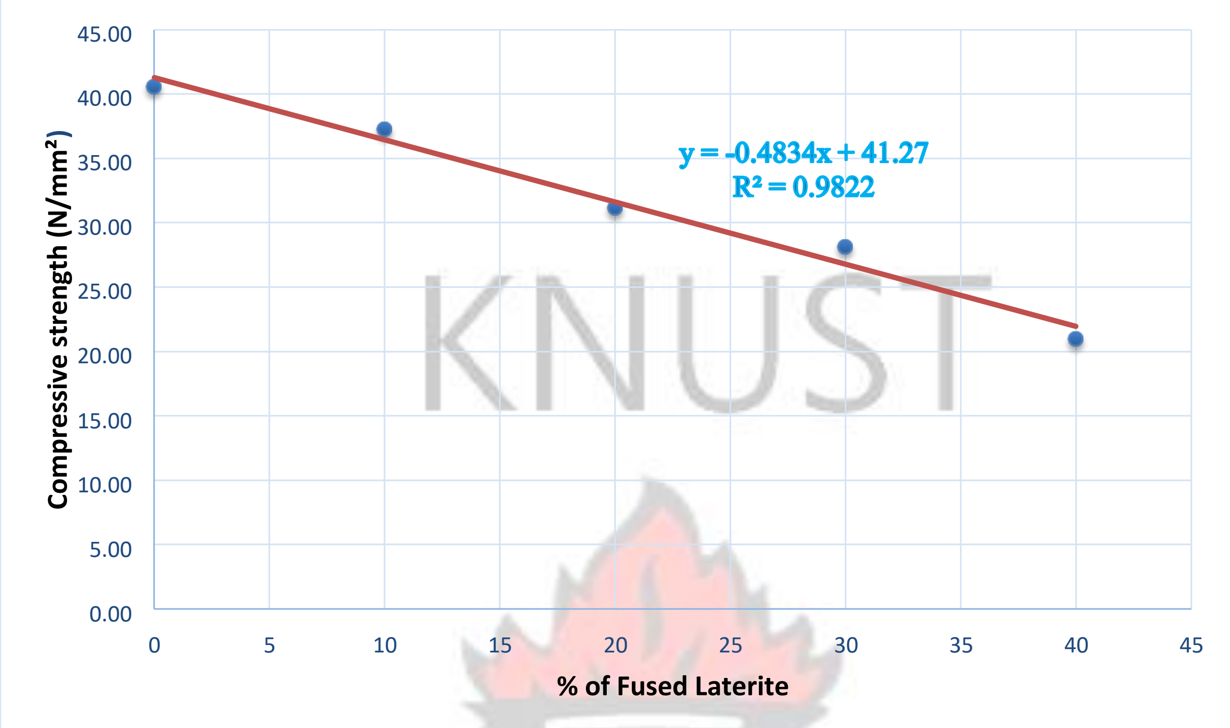

Fig 4.2: Compressive strength at 28 days

4.3.2 Split Tensile Strength

Fig 4.3 shows the indirect tensile strength of concrete produced with fused laterite. The result is not different from that of the compressive strength test. It was found that the split tensile strength decreases as the amount of fused laterite in a given concrete increases. As explain earlier on, this phenomenon can be attributed to the low silicate content in fused laterite.

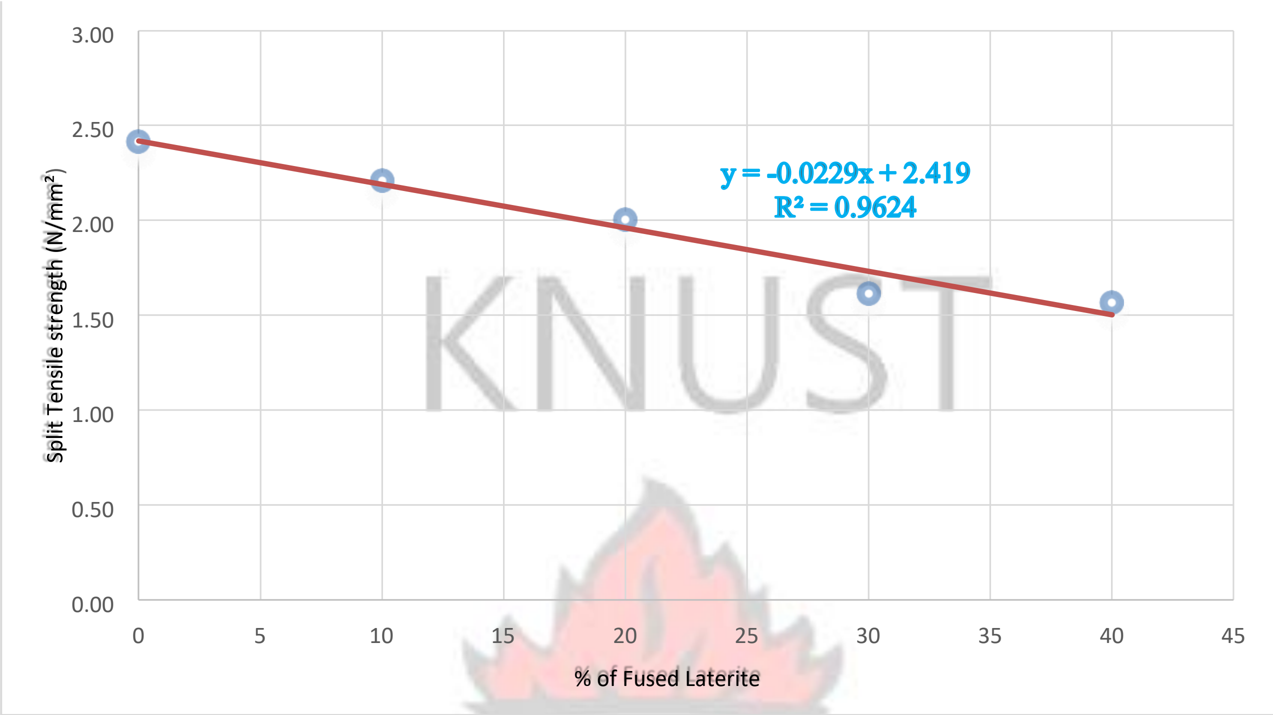

Fig 4.3: Split Tensile strength at 7 days

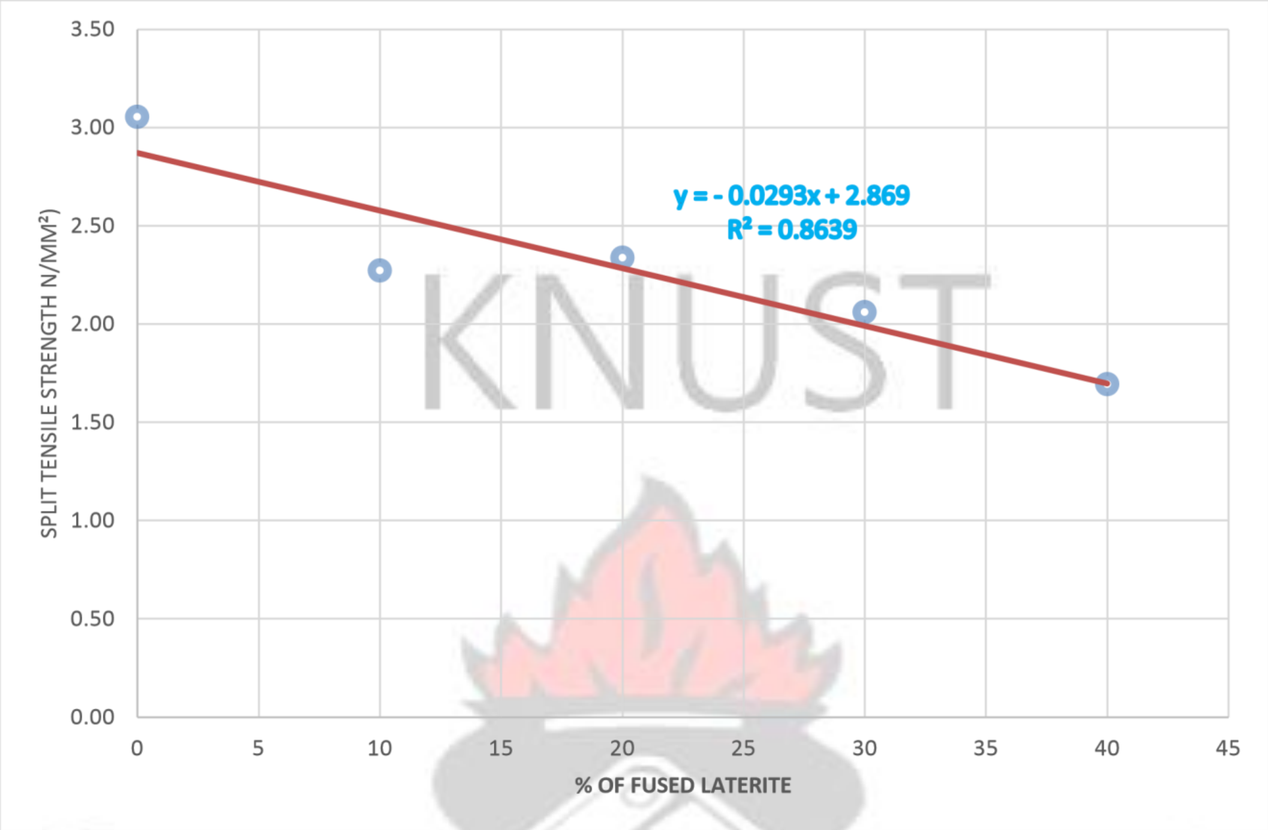

Fig 4.4: Split Tensile strength at age 28 days

Fig 4.5 shows the relationship between the split tensile strength (f_{st}) and the compressive strength (f_{cu}) of concrete with fused laterite in terms of its compressive strength. From the graph, as the compressive strength of concrete increases, the split tensile strength also increases. That is, there is a positive relationship between the two variables. The above findings in not different from the report by Nihal (2006) here a positive correlation was found between the compressive of concrete and its split tensile strength.

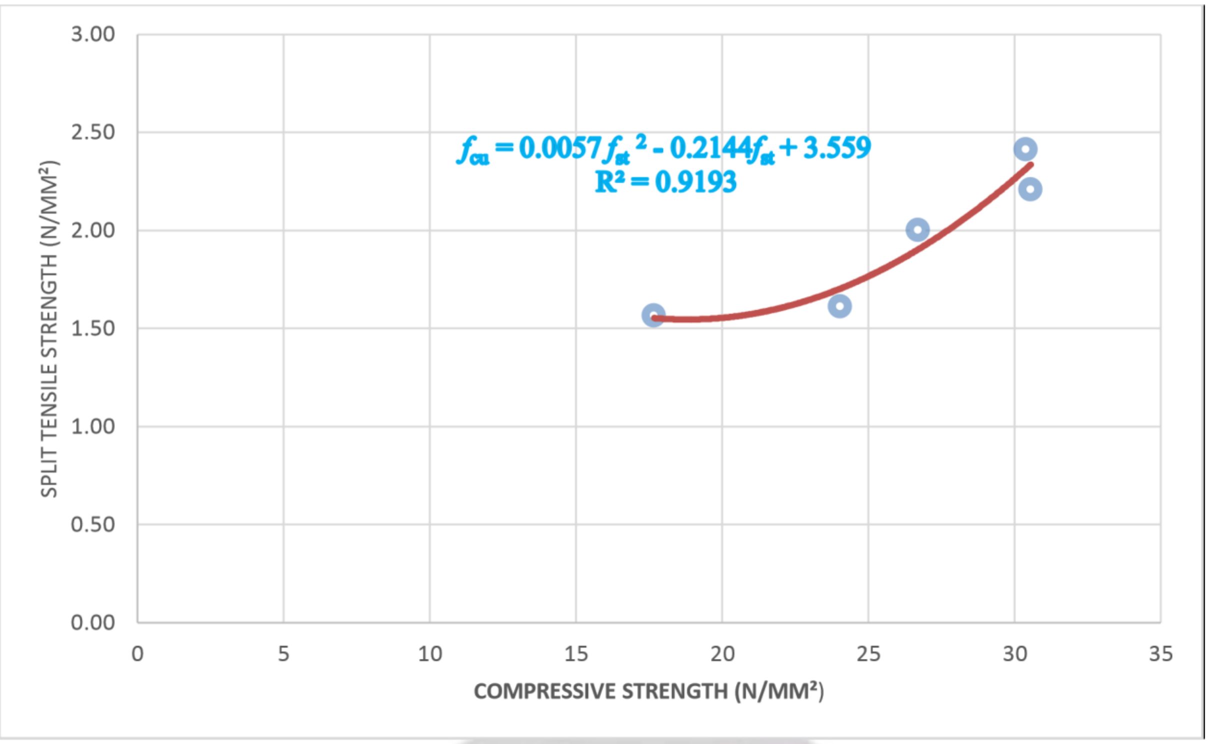

Fig 4.4: Relationship between the compressive strength and the split tensile strength of concrete with fused laterite

4.4 SUMMARY

In this chapter, the chemical composition of fused laterite have been discussed. The influence of the chemicals on the strength of concrete have also been presented. The findings from chapter has led to the conclusions been drawn in chapter five.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

The current study was designed to determine the chemical properties of fused laterite as well as its influence on the compressive and split tensile strength of concrete. To achieve this series of laboratory test were carried out. This chapter presents the key findings and the conclusions drawn from the study.

5.2 SUMMARY OF FINDINGS AND CONCLUSION

The following are the key findings and conclusions drawn from the study:

Objective 1: To determine the chemical composition of fused laterite The results revealed that:

(i) The most dominant chemicals in fused laterite are Calcium Oxide (CaO) which represents 19.2% followed by Silica oxide (2.8%), Sulphur oxide (2.5%), Magnesium oxide (1.94%), Sodium oxide (0.06%), Potassium oxide (0.04%) and Sulphur oxide (2.5%)

(ii) Fuse laterite contains a majority of the oxides (chemicals) present in Ordinary Portland cement. It is therefore not surprising that fuse laterite exhibits the properties of cement.

(iii) Notwithstanding the above, the quantity of the chemicals in fused laterite are small compared with that in Portland cement thereby making it difficult to be used solely as the binding agent in concrete production.

Objective 2: To find the Compressive strength of concrete made of partial replacement of fused laterite powder and Ordinary Portland cement

The following were found:

(i) Fused laterite has retrogressive effect on the compressive strength. In other words, irrespective of the age of the concrete, fuse laterite reduces the compressive strength of concrete as it's (i.e. the fuse laterite) content in the mix increases.

(ii) The above effect can be attributed to the fact that fused laterite contains little amount of silicate (the primary chemical responsible for strength development). Thus, as more of the fused laterite is used, the content of silicate in the mix is reduced hence a weak concrete is produced

Objective 3: To find the Split tensile strength of concrete made of partial replacement of fused laterite powder and Ordinary Portland cement

(i) The results revealed that fuse laterite reduces the split tensile strength of concrete as it's (i.e. the fuse laterite) content in the mix increases

5.3 RECOMMENDATIONS

The study results have proven that fused laterite has a chemical composition similar to that of ordinary cement hence there is the possibility of using it as binding agent in concrete production. However, the difficulty lies in the fact that, the content of the chemicals in the fused laterite is small which means one cannot rely on it solely for concrete production; it should be combined with cement. Hence, it recommended that further studies should be carried out to find out the best way this local material can be effectively used in the production of cement.

5.4 FURTHER STUDIES

It is recommended that further studies should be conducted in the following areas:

(i) The effective way of using fused laterite in the production of cement.

(ii) Effect of age on the strength of concrete produced with fused laterite.

(iii) Structural properties of the laterite concrete.

(iv) The type of additive that can improve its strength.

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APPENDIX A

LABORATORY TEST RESULTS

Table 1: Sieve Analysis of Sand

B S Sieve Size Metric (mm)	Weight Retained (g)	Percentage Retained (%)	Percentage Passing (%)
4.75			100

3.35	0.35	0.175	99.825
2.00	3.04	1.52	98.305
1.00	26.67	13.335	84.97
0.600	26.42	13.21	71.76
0.425	19.45	9.745	62.015
0.300	22.52	11.26	50.755
0.150	45.32	22.66	28.095
0.075	33.28	16.64	11.455

Table 2: Sieve Analysis of Coarse Aggregate

B S Sieve Size Metric (mm)	Weight Retained (g)	Percentage Retained (%)	Percentage Passing (%)
13.20			100
9.50	27.03	6.286	93.714
6.70	187.20	43.535	50.179
4.75	172.79	40.184	9.995
3.35	40.40	9.395	0.600
2.00	1.10	0.256	0.344
1.00	0.05	0.012	0.332

Table 3: Compressive strength of concrete cubes at age 7 days

Percentage of fused laterite (%)	Weight (Kg)	Load (KN)	Strength (N/mm²)	Average cube strength (N/mm²)
0.0%	8.317	815.3	36.24	35.38
	8.174	789.2	35.07	
	8.245	783.3	34.82	
10%	8.221	704.4	31.31	30.54
	8.228	649.4	28.86	
	8.268	707.7	31.45	

20%	8.315	593.1	26.36	26.68
	8.275	603.8	26.83	
	8.273	604.4	26.86	
30%	8.291	571.7	25.41	24.02
	8.253	527.0	23.42	
	8.128	522.6	23.23	
40%	8.024	415.6	18.47	17.66
	8.283	376.1	16.72	
	8.291	400.3	17.79	

Table 4: Compressive strength of cubes at the age of 28 days

Percentage of fused laterite (%)	Weight (Kg)	Load (KN)	Strength (N/mm²)	Average strength (N/mm²)
0	8.234	885.6	39.36	40.550
	8.167	945.8	42.03	
	8.231	905.7	40.26	
10	8.337	861.1	38.27	37.247
	8.316	821.4	36.50	
	8.291	831.7	36.97	
20	8.235	734.9	32.66	31.147
	8.264	727.9	32.32	
	8.353	639.6	28.43	
30	8.204	630.9	28.04	28.129
	8.333	640.8	28.48	
	8.465	627.0	27.87	
40	8.207	453.1	20.14	20.941
	8.385	480.4	21.35	
	8.234	480.0	21.33	

Table 5: Split Tensile Strength of concrete at age of 7 days

Percentage of fused laterite (%)	Weight (kg)	Load (KN)	Split tensile strength N/mm^2	Average strength (N/mm²)
0.0 %	12.801 12.554 12.716	169.2 167.2 175.0	2.39 2.37 2.48	2.413
10 %	12.665 12.771 12.857	168.3 129.6 171.4	2.38 1.83 2.42	2.210

20 %	12.502 12.579 12.511	160.8 119.8 144.7	2.27 1.69 2.05	2.003
30 %	11.899 12.218 12.390	118.9 98.6 133.3	1.68 1.27 1.89	1.613
40 %	12.412 12.398 12.241	114.4 110.5 107.8	1.62 1.56 1.52	1.567

Split Tensile strength test at age 28 days

Percentage of fused laterite (%)	Weight (kg)	Load (kN)	Strength (N/mm²)	Average strength (N/mm²)
0	12.752	220.900	3.124	3.054
	12.737	206.200	2.916	
	12.648	220.800	3.122	
10	12.721	142.000	2.008	2.270
	12.581	198.100	2.801	
	12.74	141.500	2.001	
20	12.475	176.000	2.489	2.336
	12.182	136.100	1.925	
	12.497	183.400	2.594	
30	12.467	127.900	1.809	2.060
	12.298	155.400	2.198	
	12.498	153.700	2.174	
40	12.014	125.800	1.779	1.693
	12.31	123.800	1.751	
	12.194	109.600	1.550	

APPENDIX B

PROJECT PICTURES

Fig 1: Fused Laterite (Rock) before breaking into bolder sizes

Fig 2: Fused laterite powder